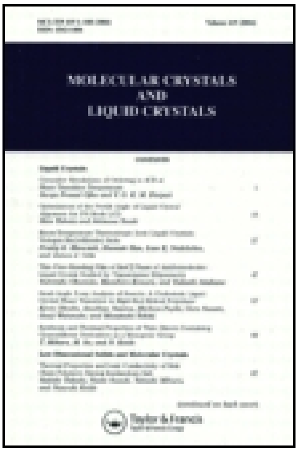


Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

The Investigation of Dielectric Properties of the Nematic Liquid Crystal in Superthin Layers

A. N. Chuvyrov [a] , G. A. Mukhamedjarova [a] & Z. Kh. Kuvatov [a]
[a] Bashkir State University, 450074, Ufa, Russia
Version of record first published: 04 Oct 2006.

Mol. Cryst. Liq. Cryst. 1995, Vol. 265, pp. 501–508
Reprints available directly from the publisher
Photocopying permitted by license only

THE INVESTIGATION OF DIELECTRIC PROPERTIES OF THE NEMATIC LIQUID CRYSTAL IN SUPERTHIN LAYERS

A. N. CHUVYROV, G. A. MUKHAMEDJAROVA, Z. Kh. KUVATOV
Bashkir State University, 450074 Ufa, Russia

Abstract In this work, the complex permittivity measurements on nematic liquid crystals which form superthin layers between mica surfaces have been performed. Using 'time domain reflectometry, at frequencies between 1MHz and 1GHz, we observe influence of solid surfaces on dielectric characteristics of nematic liquid crystals with different values of dielectric anisotropy.

INTRODUCTION

It is known, that the influence of the solid substrate leads to strong changes of physical parameters of nematic liquid crystals in boundary layers [1, 2].

However, the nature of this phenomenon is not clarified yet. In this work the results of the investigation of dielectric properties of the system of thin planeparallel liquid crystal layers, formed between mica surfaces are presented. As it was expected, these layers must behave as ferroelectric nematic layers. There are few reasons for such assumption. In thin layers under the influence of solid boundary surfaces, we have more lower symmetry than one in the bulk nematic. Mentioned fall of symmetry is connected with retarded rotation of molecules around long axes, with origine of the helical structure because of non-coincidence directions of light orientation on boundary surfaces and with polarization of mesophase which can be induced by solid walls.

EXPERIMENTAL

Measurement

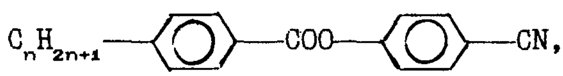
The average thickness of microlayers, determined by spectrophotometer was equal to 0,1 μm. The obtained sandwich which has summary thickness of 0,3 mm, was placed at the end of the measuring coaxial line of the time domain reflectometer. The applied electrical field was perpendicular to layers. Therefore, using equations for laminated dielectric, we can calculate the dielectric permittivity of the nematic liquid crystal, filling flat capillaries. Such NLC can be termed as micronematic as its properties differ from the properties of the bulk nematic (macronematic). It should be noted that the dielectric properties of used mica were frequency independent in the our investigation frequency range.

Because of small dielectric loss in the mica, the loss in the micronematic assumed equal to the loss in system liquid crystal-mica.

To compare dielectric properties we have measured macronematics, also. In this case thickness of the sample was 0,3 mm.

Materials

As subject of the research two nematogens were taken: mixture of the following compounds



, n=4, 6, 7

and p-p′-butyl-heptanoyloxy-azoxybenzene (BHAOB).
The nematic range of the mixture is 20-47°C. This mesophase shows considerable positive dielectric anisotropy. BHAOB has nematic state between 20 and 79°C with dielectric

anisotropy no less than -0,5.

As known from polarization - optical observations, molecules of these nematogens are oriented parallel to the cleaved mica surface. Hence, we assume that in thin layers of liquid crystal formed between mica sheets the planar orientation exists also.

EXPERIMENTAL RESULTS AND DISCUSSION

The plots of the temperature dependence of the dielectric permittivity of mesogens, which was obtained at the frequency 1MHz are presented in Fig. 1*. Apparently, the dielectric permittivity of the micronematic is more higher than that of the corresponding macronematics. The difference was observed in both the mesophase and the isotropic phase.

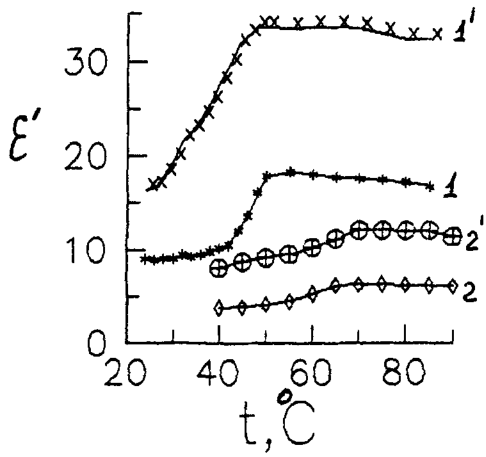


FIGURE 1 Temrature depences of ε' for nematic and isotropic phases at 1 MHz. 1, 1' - mixture, 2, 2' - BHAOB.

The following explanation may be done to this fact. In the case of the thick layer there is dipole-dipole mo-

---

* Here and hereafter the designation with a stroke (×, +) corresponds to thin layers.

lecular interaction, which causes weakening effective dipole moment of molecules μ_{eff} (antiparallel association). To take into account of the molecular interaction in [3] correlation factors were introduced:

$$\mu_{\parallel\, eff}^{2} = g(\mu_{\parallel})\mu_{\parallel}^{2},$$

$$\mu_{\perp\, eff}^{2} = g(\mu_{\perp})\mu_{\perp}^{2} ,$$

where $g(\mu_{\parallel})$, $g(\mu_{\perp})$ - the factors of dipole-dipole correlation, $\mu_{\parallel}$, $\mu_{\perp}$ - components of the molecular dipole moment.

In thin layer under the action of solid surfaces the antiparallel molecular association will be replaced by the parallel association.

It should be noted, that the surface of a solid body exerts the strong influence on both the phase state of liquids and the liquid crystals. For example, near the solid surface in liquids the molecular ordering of the mesophase type was observed. In the case of NLC the increased nematic potential causes the rise of the clearing temperature[4]. But in our work we can not detect such small effect.

In Fig. 2, 3 dispersion data are presented. The frequency dependence of complex dielectric permittivity of macronematics ε^* can be presented as following:

$$\varepsilon^{*} = \varepsilon_{\infty} + \frac{\Delta\varepsilon_{l}}{1+(jw\tau_{l})^{1-\alpha_{l}}} + \frac{\Delta\varepsilon_{h}}{1+(jw\tau_{h})^{1-\alpha_{h}}},$$

where $\Delta\varepsilon_{i}$ and τ_{i} - value of the dielectric relaxation and relaxation time of i process, respectively, α_{i}-parameter of distribution, ε_{∞} - permittivity at the ultra-high frequencies. Symbols l and h means low and high frequency processes respectively. Obviously, the mechanisms causing of

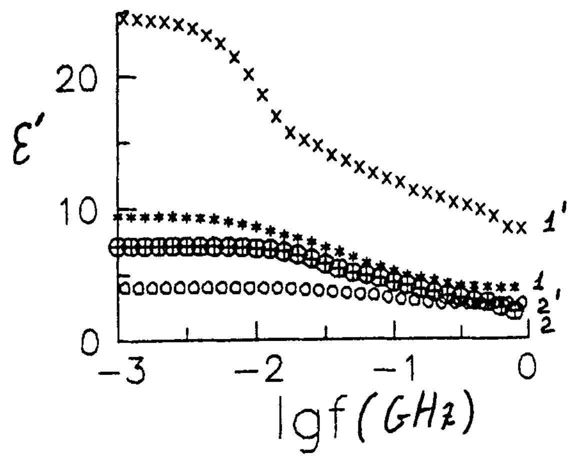


FIGURE 2 Frequency dependences of dielectric permittivity ε' for nematics obtained at 38°C (1, 1'-mixture, 2, 2'-BHAOB).

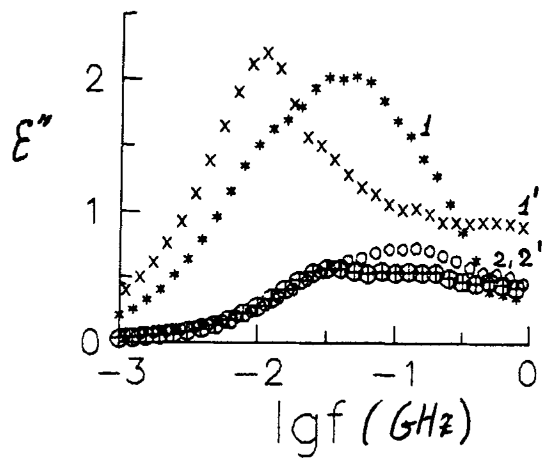


FIGURE 3 Frequency dependences of dielectric loss ε" for nematics obtained at 38°C (1, 1'-mixture, 2, 2'-BHAOB).

presence of two ranges of dispersion as related to the rotation of molecules around long axes (low frequency range) and the rotation of polar groups of molecules. In this case the strong dependence of τ_l on temperature can be explained in terms of the variation of conditions of short-range and long- range orders.

The dispersion processes in micronematics have more complicated character than in bulk samples. This fact confirms our supposition that a dipole-dipole interaction leads to the different molecular association in samples of different thickness. Noteworthy, that the decrease of the thickness of nematic layers leads to the displacement of the spectra to the low frequency range. The such result is the consequence of the polarization of the micronematic sample. As it is known, that cooperative effects are always related to the increasing of the relaxation time.

The Coul-Coul plots (Fig. 4) indicate that the passing from macro- to micronematic was accompanied by the increasing of the dielectric increment $\Delta\varepsilon=\varepsilon_0-\varepsilon_\infty$. This observation confirms the supposition that with reducing of the thickness of layer the antiparallel association turns into the parallel association.

We can take into account the influence of the boundary solid surfaces on the nematic phase by using the nematic potential q. In the micronematic value of q is higher than in the bulk mesophase.

This has an effect on the temperature dependence of the relaxation time as:

$$\tau \sim \exp\,[(q+q_v)]/kT.$$

Here q and q_v are coefficients of mean field and viscosity, respectively. The plots of $ln\ \tau_l=f(1/T)$ for micro- and

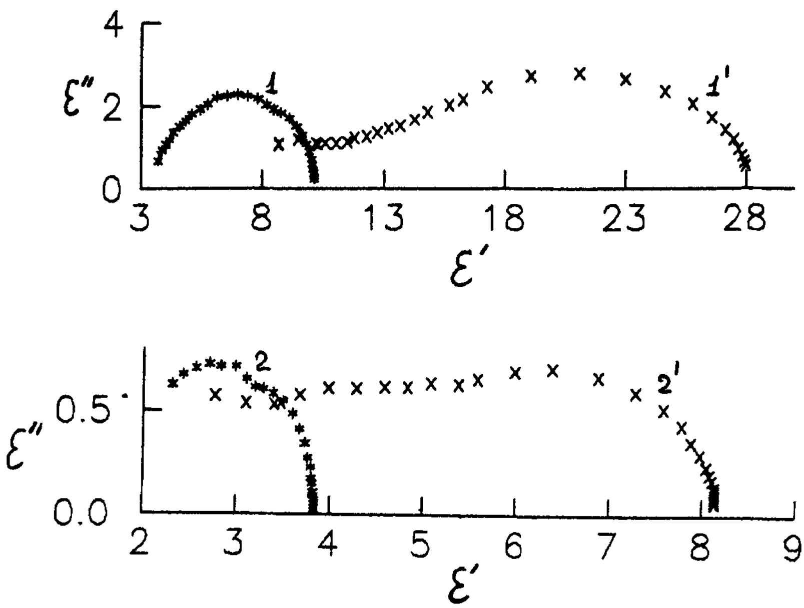


FIGURE 4 Cole-Cole plots for nematics obtained at 40°C (1, 1′ -mixture, 2, 2′ -BHAOB).

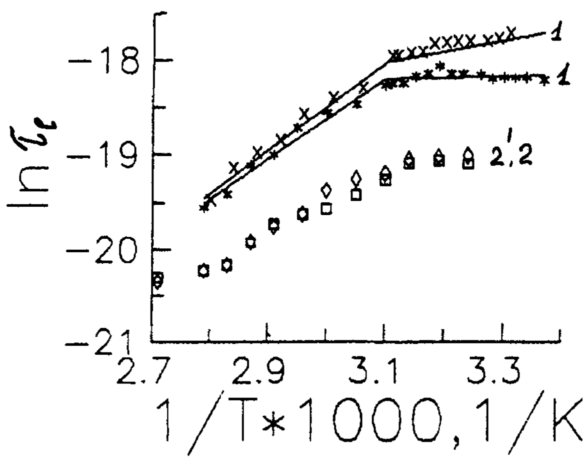


FIGURE 5 Temperature dependences of relaxation time ($ln\ \tau_l$) in nematic and isotropic phases (1,1′ -mixture, 2, 2′-BHAOB).

macronematic are presented in Fig. 5.

SUMMARY

We have observed significant difference between dielectric properties of the bulk nematic and the properties of the same nematic filling flat capillary between mica plates.

REFERENCES

1. L. M. Blinov, I. I. Kats, A. A. Sonin, Usp. fiz. nauk., v2, 449, (1987).
2. K. Miyano, Japan. J. Appl. Phys., 24, 1379, (1985).
3. W. H. De Jeu, T. W. Lathouwers, and P. Bordewijk, Phys. Rev. Lett. 32, 40, (1974).
4. F. M. Aliev, Izv. Akad. Nauk USSR, 53, 1904, (1989).